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The Structure-Based Expert Model of the Mental Disorders – A Validation Study

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Key Words
Mental disorder · Cognitive map · Expert model · Knowledge structure · Nonmetric multidimensional scaling · Procrustes transformation · ICD-10

Abstract
Background: In an earlier study, our research group presented an alternative approach to measuring knowledge about mental disorders by constructing a structure-based expert model of the ICD-10 mental disorders. This article presents a validation of this expert model by measuring the emergence of such knowledge structures in psychotherapy students. ***Sampling and Methods:*** The participants of a continuing education program in cognitive behavioral psychotherapy rated a selection of mental disorders based on their phenomenological similarity. The similarity judgments of each student were translated by nonmetric multidimensional scaling (NMDS) into a cognitive map. In a quasi-longitudinal section design, the maps of the students of the first to the fourth year of training were compared with each other and with an expert map (the expert model) of experienced therapists. ***Results:*** The discrepancies of the trainee maps compared with each other and with the expert map significantly decreased with increasing training level. ***Conclusions:*** The convergence of the students' maps towards the expert model indicates that the structural knowledge about mental disorders of experienced therapists can also be found to be emerging in psychotherapy students. This finding supports the validity of the expert model and may reflect a general knowledge-structuring principle of the mental disorders. In spite of the statistical significance found, in view of the small number of participants in the third and fourth years of training, the results should be treated with caution and should be regarded as first indicators which need further confirmation.

Introduction

Knowledge about mental disorders is an important pillar of psychotherapeutic competence [1]. It is also a focus of interest in psychiatry, as is shown, for instance, in a current study regarding the free movement of the medical workforce across European Union country borders [2]. The latter study also indicated the need for additional methods of measurement other than multiple-choice questions to measure knowledge about mental disorders. In a recent study [3], our research group presented a structure-based expert model of the ICD-10 mental disorders [4] in the form of a cognitive map, which represents a complementary method of measuring knowledge about mental disorders. The cognitive map visualizes the structural mental representation of psychotherapists and psychiatrists about mental disorders. We demonstrated that such a map reflects theoretical implications and critical observations from the literature with regard to classification systems such as the ICD-10. The evaluation showed that it was well accepted by the participating clinicians. Such a structural representation also enables categorical and dimensional aspects of the structure of the

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mental disorders to be considered and can therefore contribute to the ongoing debate [5] of whether mental disorders can be clearly delimitated from one another or whether there is a continuum between the illness entities. If – and this is the assumption to be tested in this paper – such a semantically meaningful structure, which is found to be underlying the perceptions of therapists, reflects a general knowledge-structuring principle of the mental disorders and is not merely a compromise, then it should also be found to be emerging in students. This observation should hold for students of any kind who are trained in the field of mental disorders, such as psychotherapists, psychiatrists or psychiatric nurses (even if they are not specifically trained for a specific selection of disorders). In this study, we focus on a selection of psychotherapy students. With regard to the cognitive maps, the emergence of that structure should be reflected in a convergence of the students' maps towards the expert model with an increasing level of training. In the current pilot study, we compared the cognitive maps of the students of a psychotherapeutic continuing education program in different stages (years) of their training to the map of experienced psychotherapists and psychiatrists (expert model). This procedure allows the change of the knowledge structures about mental disorders over the course of the training program to be determined and the expected convergence towards the expert model to be investigated. Thus, the cognitive maps provide a complementary method to measure factual knowledge progress.

Table 1. Selected disorders

ICD-10 code	ICD-10 nomenclature
F00.1	Dementia in Alzheimer's disease with late onset
F06.2	Organic delusional (schizophrenia-like) disorder
F07.0	Organic personality disorder
F10.3	Mental and behavioral disorder due to use of alcohol, withdrawal state
F14.5	Mental and behavioral disorder due to use of cocaine, psychotic disorder
F19.2	Mental and behavioral disorder due to multiple drug use and use of other psychoactive substances, dependence syndrome
F20.0	Paranoid schizophrenia
F20.1	Hebephrenic schizophrenia
F25.0	Schizoaffective disorder, manic type
F31.1	Bipolar affective disorder, current episode manic without psychotic symptoms
F32.2	Severe depressive episode without psychotic symptoms
F34.1	Dysthymia
F40.0	Agoraphobia
F41.2	Mixed anxiety and depressive disorder
F43.2	Adjustment disorder
F50.0	Anorexia nervosa
F50.2	Bulimia nervosa
F60.0	Paranoid personality disorder
F60.3	Emotionally unstable personality disorder
F62.0	Enduring personality change after catastrophic experience

Methods

Sample and Task

The sample consisted of the participants of a continuing education program containing the main subjects of behavioral medicine and cognitive-behavioral therapy at the University of Zurich, Switzerland [6, 7]. The 4-year curriculum is approved by the Federation of Swiss Psychologists. In the first 2 years, basics, theory and disorder-specific knowledge are taught, accompanied by self-awareness and clinical practice. In the second to the fourth year, therapeutic experiences, group supervision and case seminars are added. Of the total of 37 participants, 26 (24 female, 2 male) took part in this pilot study (first year: 14/15 participants, 13 f, 1 m; second year: 8/8 participants, 8 f; third year: 2/9 participants, 1 f, 1 m; fourth year: 2/5 participants, 2 f). The sample sizes of the groups from the third and fourth years are very small, which should be kept in mind when drawing conclusions. Nonetheless, the inclusion of these small groups permits very precise predictions about individual participants to be verified and the consistency of the tested model to be evaluated. This information would be lost if participants were subsumed in larger units of analysis.

The data collection was designed as a quasi-longitudinal section. Subjects of all 4 training levels (first to fourth year) rated 190 presented pairs of 20 disorders based on their phenomenological similarity on a scale from 1 = minimal similarity to 9 = maximal similarity (similarity judgments [8, 9]). The task was presented on a computer screen with the INTUS© data collection software [10]. Each similarity judgment between a pair of disorders is composed of an intuitively weighted sum of the essential known facts of a subject about the 2 disorders. Additionally, considering that each disorder is compared to every other disorder of the selection [$n \cdot (n - 1)/2$ pairwise combinations of disorders with n = 20 disorders], each similarity judgment is only 1 piece of the whole picture (in this case 190 similarity judgments).

The selection of the disorders comprised the 20 items that are listed in table 1. The composition is identical (except for 1 disorder) to that presented in the Egli et al. study [3], where the selection criteria are also described in detail. The nonorganic insomnia (F51.0) was excluded from the current study because experience showed that this item was sometimes perceived not as a disorder but as a symptom potentially belonging to various illness entities. This could lead to undesirable inconsistencies in the similarity judgments.

Analysis

The similarity judgments were analyzed by robust nonmetric multidimensional scaling (NMDS) by means of the ROBUSCAL

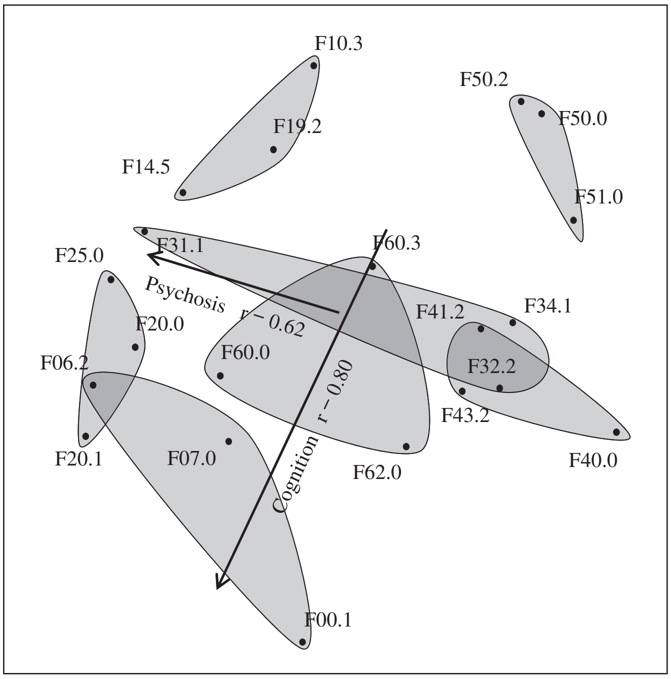

Fig. 1. Expert model of the Egli et al. study [3]. Disorders are labeled with the ICD-10 F codes; clusters are plotted according to the ICD-10 F categories (see table 1). The dimension 'psychosis' exhibits a correlation of r = 0.62, the 'cognition' dimension a correlation of r = 0.80.

algorithm [9, 11]. In an iterative process, the n-dimensional configuration with the maximal ordinal correspondence to the proximities between all disorders as defined by the similarity judgments is approximated by ROBUSCAL. In the resulting 2-dimensional Euclidian space (the cognitive map), a small distance between the objects (i.e. disorders) corresponds to a high similarity and vice versa. The following example might illustrate this process. A study participant rates the phenomenological similarity between F25.0 (schizomanic disorder) and F31.1 (bipolar mania) with a score of 9 (maximal similarity). In contrast, he judges the similarity between F31.1 and F32.2 (severe depression) to be not similar at all, with a score of 1. The NMDS translates this ordinal information (F25.0 and F31.1 are much more similar than F31.1 and F32.2) into a 2-dimensional map (considering at the same time all the covariances to and between all the other disorders as determined by the other similarity judgments). In the resulting cognitive map, the similar objects F25.0 and F31.1 are located closely together, while F31.1 and F32.2 are located further apart in opposite directions of the map. The cognitive maps were calculated on an individual basis for the trainees participating in the current study, and on the mean level for experienced psychotherapists and psychiatrists from the Egli et al. study [3]. This mean cognitive map constituted the expert model, which is presented in figure 1 (the disorders are labeled with the ICD-10 F codes and the clusters are plotted according to the ICD-10 F categories). The closer the disorders are located in the map, the more similar they were rated by the psychotherapists and psychiatrists.

In addition to the clusters, it is also possible to identify dimensions in an NMDS map. The 2 dimensions psychosis and cognition were calculated by property fitting [8, 11]. The underlying values were extracted by a content analysis from the ICD-10 diagnostic guidelines [4]. Although the dimensions are positioned nearly orthogonal to each other, it is important to stress that these dimensions do not correspond to the ones extracted by other main component analysis methods such as factor analysis. The dimensions presented here are additionally fitted into the NMDS space, for which the dimensions are not a priori determined and are free of semantic meaning. For a more detailed description and interpretation of the clusters and the dimensions, please consult the Egli et al. study [3].

The cognitive maps of all participants were compared to the expert model and to each other by means of Procrustes transformations [12] (in this study the specific PROPERSCAL algorithm was employed [11]). A Procrustes transformation compares 2 maps by scaling, shifting, rotating and mirroring the configurations to approach a maximal congruence. The remaining deviation is numerically determined as the object loss between corresponding positions of disorders on the object level and as the average loss between the 2 cognitive maps [11]. (The average loss equals the averaged object losses.) The deviation of an individual map from the expert model provides an estimate of the appropriateness of the knowledge of this participant. Additionally, another 2-dimensional map was calculated by NMDS, based on the matrix of average losses between all pairs of individual cognitive maps. This loss-oriented metamap (LOMM) represents the relational position of the subjects based on the similarity of their individual cognitive maps of mental disorders.

Results

The arrows in figure 1 (labeled 'psychosis' and 'cognition') represent the orientation of the corresponding dimensions in the map and exhibit high correlations (r = 0.80, R^2 = 0.64 for the cognition dimension and r = 0.62, R^2 = 0.38 for the psychosis dimension). The further away the orthogonal projection of a disorder is located on a dimension in the direction of the arrow, the more the emphasis of the dimension in the ICD-10 diagnostic guidelines of this disorder increases. For instance, for F00.1 (Alzheimer's dementia), which is located at the extreme of the cognition dimension, the ICD-10 diagnostic guidelines emphasize the cognitive impairment most strongly compared to the other disorders in this selection. As an example to illustrate small and large deviations of maps compared by the Procrustes transformation, figure 2 shows the resulting maps from 2 individual comparisons. The map on the left represents the result of the comparison of the individual map of subject 1.4 (first year of training, subject 4) with the expert model. The map on the right represents the result of the comparison of the individual map of subject 4.1 (fourth year of training,

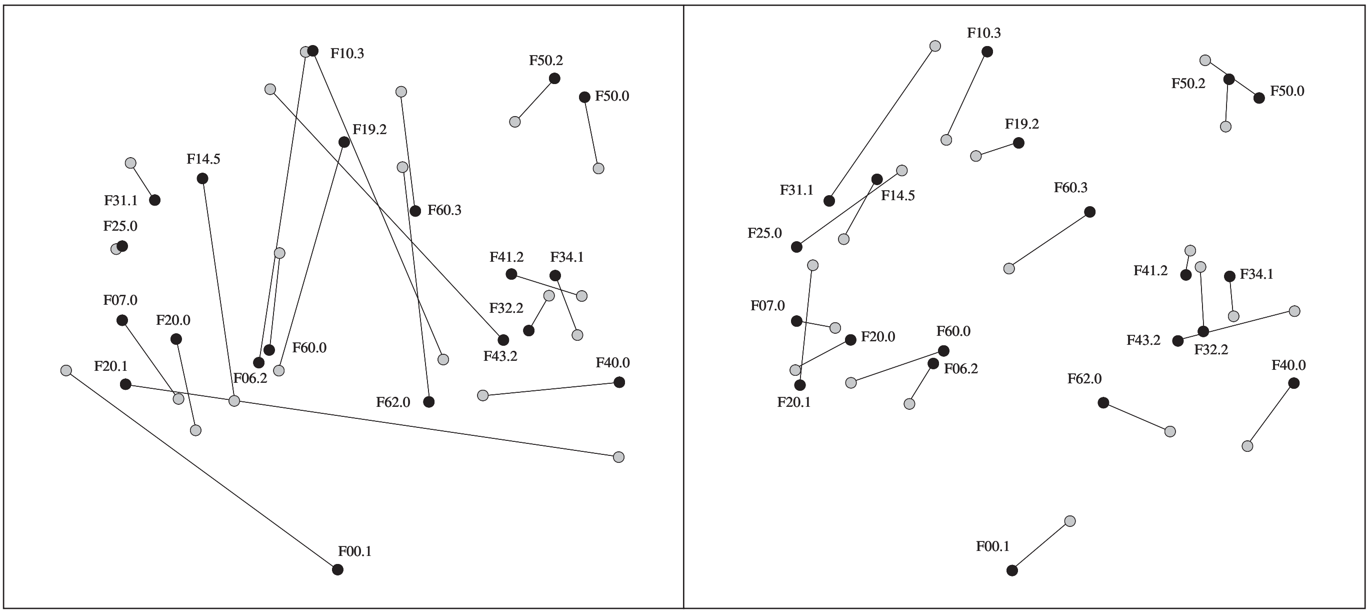

Fig. 2. Results of the Procrustes transformation of 2 individual maps with the expert model. Black dots = expert positions of the disorders; gray dots = positions of the disorders of individual subjects. The lines between the dots represent the deviations of the corresponding disorders (object losses), disorders are labeled with the ICD-10 F codes. Left: subject 1.4 (first year of training, subject 4): average loss = 0.61, right: subject 4.1 (fourth year of training, subject 1): average loss = 0.29.

subject 1) with the expert model. The deviations of the maps are reflected on the level of objects as lines (object losses) between the corresponding disorders (labeled with ICD-10 F codes [4]) and on the level of the maps as the average losses (subject 1.4, left: average loss = 0.61; subject 4.1, right: average loss = 0.29). The example of object F20.1 (hebephrenic schizophrenia) illustrates the difference between the judgments of the 2 subjects: as the expert position (black dots in fig. 2) indicates, F20.1 should be judged as similar to the other schizophrenic disorders, which would result in a location in close proximity to these disorders (F20.0: paranoid schizophrenia and F25.0: schizomanic disorder). Subject 4.1 succeeded in judging the similarity quite appropriately, which is reflected in only a small deviation (object loss) between the expert position (black dot) and the learner position (gray dot). Subject 1.4, on the other hand, judged the hebephrenic schizophrenia to be more similar to the anxiety and depressive disorders located on the right-hand side of the map. This resulted in a large divergence/object loss, which is reflected in the rather large corresponding line of deviation plotted in the map.

The average losses of all pairwise comparisons of the maps of all participating subjects plus the expert model were translated by NMDS into a LOMM (fig. 3). In this map, a small distance corresponds to a small average loss between the 2 maps, which are represented by the dots, and therefore reflects a high similarity and vice versa. In other words, 2 dots (representing 2 cognitive maps, i.e. 2 cognitive structures of 2 individuals) that are located closely together reflect a high structural similarity of the corresponding cognitive structures of the subjects. The 4 clusters are plotted around the positions of the maps of the participants according to their level of training (first to fourth year).

Figure 4 shows the mean average losses of the maps of the subjects compared to the expert model (first year: M = 0.46, SD = 0.09; second year: M = 0.42, SD = 0.01; third year: M = 0.37; fourth year: M = 0.33; the SDs of the third- and fourth-year groups are not presented as there were only 2 subjects in each of these groups). The change of the average losses (as a reminder: a low average loss indicates a small deviation of 2 compared cognitive maps and therefore argues for a high similarity of the corresponding cognitive structures) across the 4 years is statistically significant as determined by the nonparametric Kruskal-Wallis test [$\chi^2(3, 26) = 7.89$, $p < 0.05$]. Furthermore, the mean average loss of the subjects from the second to the fourth year (M = 0.39, SD = 0.09) is significantly lower than the mean average loss of the first year

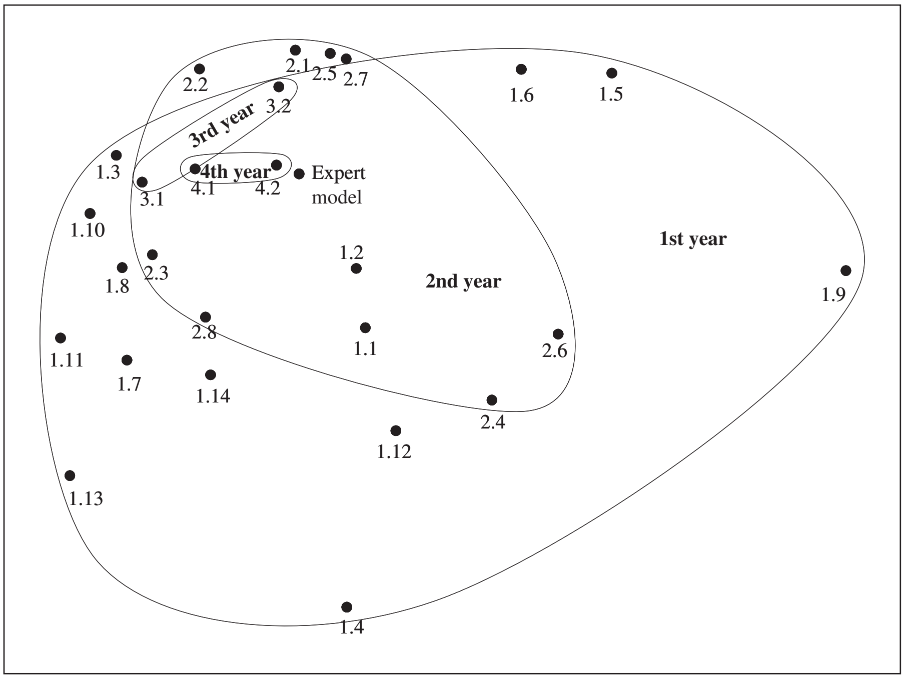

Fig. 3. LOMM; the plotted clusters depict the 4 training levels: first year = subjects 1.1–1.14, second year = subjects 2.1–2.8, third year = subjects 3.1 and 3.2, fourth year = subjects 4.1 and 4.2.

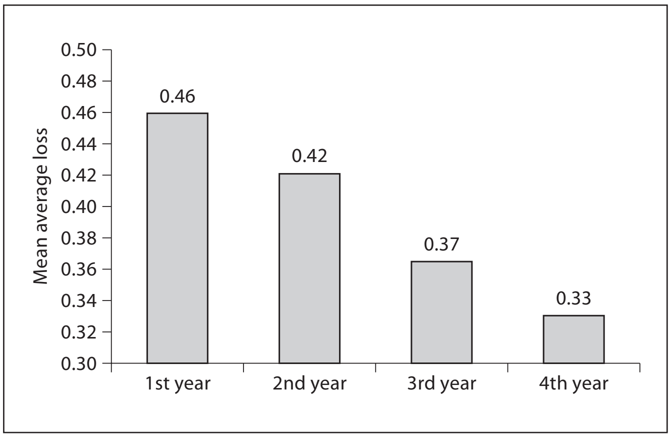

Fig. 4. Mean average losses to the expert model within the 4 training levels first to fourth year.

[M = 0.47, SD = 0.09, t(24) = 2.3, $p < 0.05$]. The interindividual average losses between the maps of the participants from the 4 levels of training are as follows: first year: M = 0.56, SD = 0.10; second year: M = 0.50, SD = 0.08; third year: M = 0.43; fourth year: M = 0.33; the SDs of the third- and fourth-year groups are not presented as there were only 2 subjects in each of these groups. Figure 5 shows the mean average losses of the individual maps of the trainees compared with the mean trainee map and the expert model (variance of the cognitive structures of the study subjects compared with their averaged model and the expert model), and the maps of the individual experts compared with the expert model and the mean trainee map (variance of the cognitive structures of the experts compared with their averaged model, i.e. the expert model, and the averaged model of the study subjects). The comparison trainees – mean map trainees with experts – mean map trainees shows a significant difference [t(43) = –2.37, $p < 0.05$].

Discussion

In an earlier study, our research group introduced a structure-based expert model of the ICD-10 mental disorders. In the current pilot study, we presented indicators supporting the hypothesis that this semantic structure, which underlies the perceptions of experienced therapists, can also be found to be emerging in psychotherapy students. To measure the progress of the semantic structure, i.e. the knowledge about mental disorders, the relational knowledge of participants of a continuing education program in cognitive behavioral psychotherapy and behavioral medicine was measured by similarity judgments. These ratings were then translated into cognitive maps by NMDS and compared to the mean map of experienced psychotherapists and psychiatrists (the expert model) by Procrustes transformations. Figure 2 illustrates the results of 2 comparisons chosen as an example. It is evident that the map of a subject from the first training year (left side: subject 1.4) exhibits a much larger structural divergence from the expert model than the map of a subject from the fourth training year (right side: subject 4.1). Both the average losses between the individual maps and the expert model (fig. 4) as well as the loss-oriented metamap (fig. 3) support the expected emergence of the semantic structure in the psychotherapy students. Another striking feature of the LOMM is the decreasing variance with increasing training level within the 4 training groups: the participants from a higher compared to a lower training level are less scattered across space and converge towards the expert model. However, although the nonparametric Kruskal-Wallis test showed significant results, the small sample size of the group from the third and fourth years should be kept in mind as a limiting aspect of the interpretations. Considering that the employed expert model resulted from an earlier study [3] and was not tailored to the continuing education program, these findings suggest a general semantic structure underlying the mental disorders that is not primarily dependent on the specific selection of the disorders.

A surprising result is the – at first glance – rather large interindividual divergence (mean average loss = 0.59, SD = 0.09) of the maps of the therapists in the Egli et al. study [3]. The comparison with the interindividual divergence of the maps of the psychotherapy students in the current study reveals that the maps of the experienced therapists are even more divergent from each other than those of the first-year students. A possible explanation for this observation could lie in a 'double-funnel model': while the students of the training program are confronted with a common learning environment and learning goal, their structures converge (the left narrowing funnel). One pillar of this common learning environment with regard to the mental disorders is the ICD-10 guidelines and criteria. As demonstrated in the results section, the dimensions underlying the expert model, which are based on these criteria, explain a high proportion of the variance of the structure towards which the trainees converge. Once they are in the field of practice, however, all individuals experience different groups of patients, various continuing education programs with varying theoretical orientations, and so on. It is plausible to assume that these individual experiences can lead to a larger divergence of the knowledge structures (the right opening funnel). This assumption is also supported by the fact that the trainees are closer to the mean trainee map than the experts are to the mean expert map and indeed that the trainees are closer to the mean expert map than the experts, presented in figure 5. Nonetheless, it should also be emphasized that the individual experts differ unsystematically from the mean expert model (which is very well replicated by the average loss of only 0.25 between the mean learner model and the expert model). For this reason, the presented expert model can be used as a 'standard' upon which everybody could agree in general, despite the fact that individual experience leads to deviations for certain parts of the structure. Furthermore, the fact that the trainees are closer to the mean expert map than the experts are to the mean trainee map also supports the assumption of a double-funnel model, where the trainees converge towards a target model and the experts diverge again away from it. (It should be mentioned that a further reason for the large discrepancy of the individual maps of the therapists might also be found in the change of the criteria for the judgments described below.)

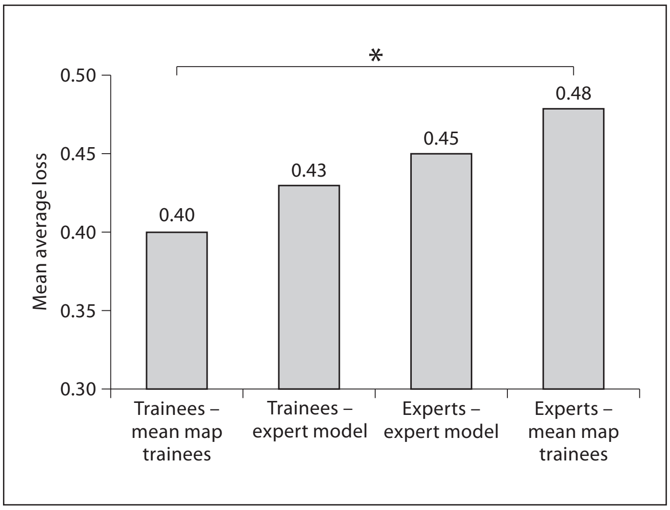

Fig. 5. Mean average losses of the individual maps of the trainees compared with the mean trainee map and the expert model, the maps of the individual experts compared with the expert model and the mean trainee map. The comparison trainees – mean map trainees with experts – mean map trainees differs significantly [$t(43) = -2.37$, * $p < 0.05$].

The findings of this study can certainly be seen as providing first evidence for the usefulness of measuring structural knowledge about mental disorders with cognitive maps. As we have seen, the structural knowledge of each individual is composed of a set of similarity judgments, which are themselves composed of an intuitively weighted sum of the essential known facts of a subject about the compared disorders. Thus, the method of similarity judgments and cognitive maps offers an innovative approach to combine factual and structural knowledge in 1 assessment. At the same time, there are some restrictions regarding the interpretability of the results presented in this study. First, the criteria for the similarity judgments (the calculation basis for the cognitive maps) were restricted in this study to the phenomenology of the mental disorders. In the expert model study [3], the criterion for the judgments consisted in the similarity of the mental disorders based on the clinical experience of the participating psychotherapists and psychiatrists and might therefore also involve other criteria such as etiology, severity, etc. Therefore, the semantic basis of the judgments and consequently also of the cognitive maps of the psychotherapy students and the expert model are not identical. Furthermore, of course, the knowledge assessed here is limited to the criteria of phenomenology and does not involve important knowledge aspects such as those mentioned above. Second, although the decrease of the average losses is statistically significant and also evident in the LOMM, due to the small number of participants in the third and fourth years, these results should be interpreted as trends or first indicators rather than statistically confirmed facts.

There are 2 main reasons for the restriction to the phenomenology criterion in this study. First, with this data basis, it can be expected that the cognitive maps better correspond to the main focus of current classification systems such as the ICD-10, which is also based on the phenomenology of mental disorders [13–15]. Second, experience resulting from the construction of a new expert model within the framework of an e-learning tool [16] indicates that such a restriction can lead to a smaller variance between the maps of the experts and hence promote a more consistent expert model. Nevertheless, it should be mentioned that the mismatch of the judgment criteria can be expected to lead to an underestimation of the performance of the presented method. The focus on the phenomenological similarity of the disorders also has a desirable advantage for the training of clinicians in terms of preparing them for daily routine, which is a contribution to the clinical utility of these results. An important diagnostic challenge of daily routine is the aspect of differential diagnosis. To master this challenge, it is important to keep an overview of the similarities of the diagnostic criteria, which (as mentioned above) are for the most part based on symptoms and therefore on phenomenological aspects. This ability is exactly what is conveyed by the task of assessing the relational similarities of the disorders, as it had to be carried out by the participants of this study.

In conclusion, these first results represent a promising basis for further studies with more subjects. There is evidence for a general structure underlying the knowledge about mental disorders in experienced therapists and in psychotherapy students. The cognitive maps allow such structural knowledge to be explored and their change to be measured. This approach of measuring structural knowledge was successfully implemented in the e-learning environment Psychopathology Taught Online [17–19], which is now used in most universities in Switzerland and the University of Salzburg in Austria. Beyond the detection of differences in the cognitive structures of the students and the experts, Psychopathology Taught Online also allows misconceptions of individual students about single disorders to be detected. Based on the deviation of these disorders, Psychopathology Taught Online offers automatically constructed exercises, which are individually tailored to each student according to his or her most prominent misconceptions. Furthermore, the relational structure of the mental disorders can be modeled not only on the knowledge level but also on a symptomatic clinically oriented level. Our research group is currently submitting the results of the analysis of symptom profiles of patients with mental disorders. Based on these symptom profiles, it is possible (by employing the presented method of NMDS) to calculate not cognitive maps but rather maps of symptoms and patients [unpublished data]. From an applied clinical perspective, the combination of the symptom with the patient maps can be implemented in a diagnostic tool, which offers a quick and automated diagnostic embedding of a patient. From a research perspective, new insights beyond the results of traditionally employed statistical methods in terms of categorical and dimensional classification issues can be gained. Although for the most part we were able to confirm the diagnostic entities of the currently used classification systems such as the ICD-10 or the DSM-IV, there are also findings contributing new aspects to the discussions in various diagnostic areas. Such areas include the manic-depressive continuum (e.g. [20]) or the difficulty of delineating affective and anxiety disorders (e.g. [21, 22]), which are aspects that are already hinted at in the expert model used in this study. Contributions to other debated areas include the distinction and structure of affective and schizophrenic disorders (e.g. [23–25]) or various psychotic illness entities (e.g. [26, 27]) [unpublished data].

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